

Predictions, Performance and Real World Results

What can we learn from 160,000 houses in Houston?

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▶ Predictions, Performance & Real World Results

Outline

- ▶ Assess programs with real world data – bill analysis
- ▶ Studies done to date
- ▶ Data Analysis, Results and Conclusions
- ▶ Where do we go from here?



▶ Objectives

- ▶ Using actual consumption data, assess new construction programs in different markets to determine:
 - > Usage across different groups or programs
 - > Predicted vs Actual Savings
 - > Strategies that result in energy savings



▶ Wisconsin ENERGY STAR Homes Study

"Energy Savings from the Wisconsin ENERGY STAR Homes Program", S. Pigg, ECW 211-1, Oct 2002

- ▶ "Best" evaluation of ENERGY STAR Homes program
 - > 1999/2000 new ES homes and non ES homes

- ▶ Key Findings
 - > Gas Usage
 - ES Home = 928 th/yr (97 homes)
 - Non ES Home = 1024 th/yr (157 homes)
 - Savings = 96 th/yr, 9%
 - Savings attributed to tighter buildings
 - Lack of saving due to the presence of high efficiency furnaces

 - Both groups similar to state average use due to larger size



▶ Wisconsin ENERGY STAR Homes Study

"Energy Savings from the Wisconsin ENERGY STAR Homes Program", S. Pigg, ECW 211-1, Oct 2002

▶ Projected Usage

- > HERS projections 10% high, attributed to duct leakage assumptions
- > 56% of homes within $\pm 20\%$, 25% of homes within $\pm 10\%$
- > But living area was nearly as good a predictor as the rating:
 - sq.ft. accounted for 50% of variation, REM projected accounted for 52%



▶ New York ENERGY STAR Homes

- ▶ Part of NYSERDA-sponsored project to assess design options to reach HERS 90 (score)
 - > VEIC prime contractor
- ▶ Reviewed ratings data on 1,974 ES homes
 - > Upstate NY, built 2004 to late 2006
 - > Most Homes scored 87-89, 96 homes scored >90
- ▶ Assessed actual gas and electric usage to examine how real world performance varies



▶ NY: Actual vs. Projected Heating Use

- ▶ REM-projected usage averaged: 1,190 total therms
 - > 881 heat vs. 804 actual
 - > 309 base vs. 265 actual
 - > REM over-predicted by ~10% on average
 - > Correlation pretty good, but house size drives much of the relationship



▶ NY: Modeling Discrepancies

- ▶ HERS Scores apparently not related to energy usage within 86-89 range
- ▶ REM estimates of heating loads from walls, infiltration, windows, and ceilings are correlated with actual usage
 - > better predictor of usage than total projected load
 - > Slightly better than using just areas and CFM50
- ▶ REM estimates of duct losses and foundation losses had no discernible relation to measured gas usage
 - > Duct testing doesn't reduce heating usage (duh?)
- ▶ 2x6 walls don't seem to save as much as projected



▶ NY: Electric Usage Results

- ▶ Usage averaged 11,040 kWh/yr (~\$1,650/yr)
 - > 9,333 kWh baseload
 - > 829 kWh winter/heating load
 - > 878 summer/cooling loads
 - Homes with central AC used 990 kWh summer/cooling vs. 896 kWh projected cooling
 - But homes without Central AC used 814 kWh
- ▶ Electric usage is higher than average residential customer (~8,000 kWh/yr)
 - > house size and luxury



▶ Energy Use of New Homes In Phoenix

- ▶ Examined 7,165 homes built 1995 - 2004
 - > 3 primary efficiency categories:
 - 3,339 baseline homes
 - 2,998 ENERGY STAR homes
 - 828 Guaranteed Performance homes
 - > 6 major production builders
 - > Not a designed experiment, not a random sample

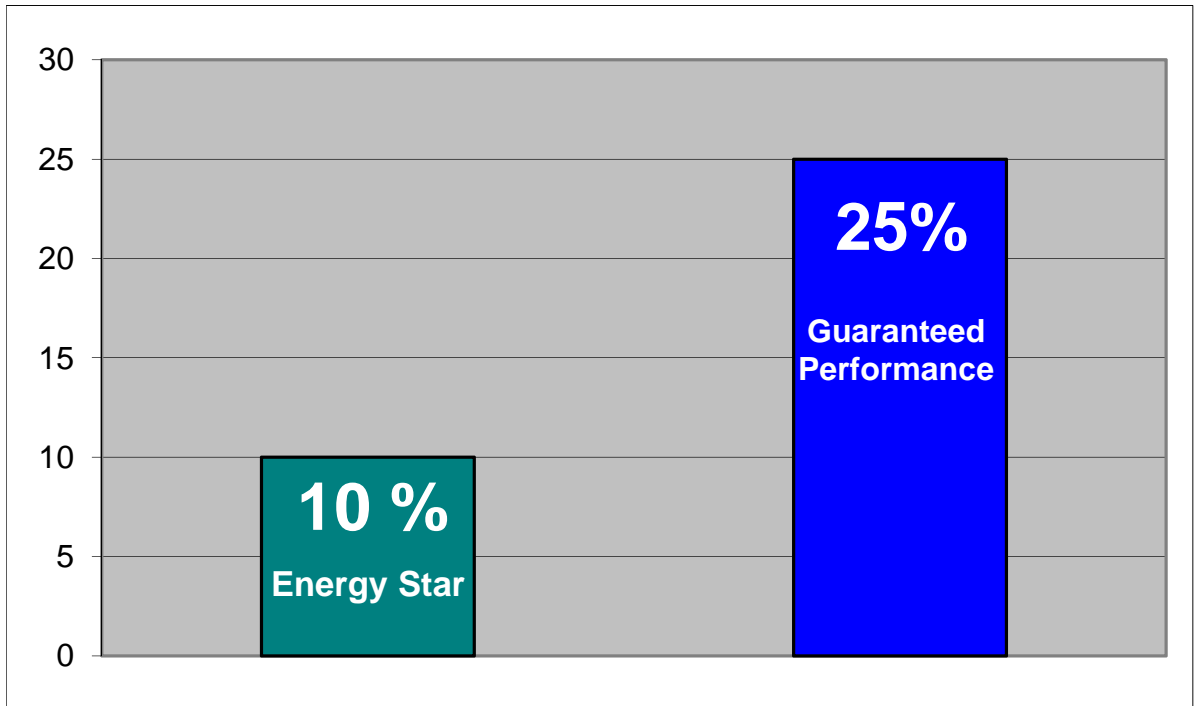


► Cooling Efficiency Results from 7141 Homes in Phoenix, AZ

For cooling, **ENERGY STAR** homes were 10% more efficient than standard built homes.

Guaranteed performance homes were 25% more efficient than standard built homes.

Improvement In Cooling Efficiency Over A Comparable Standard Built Home

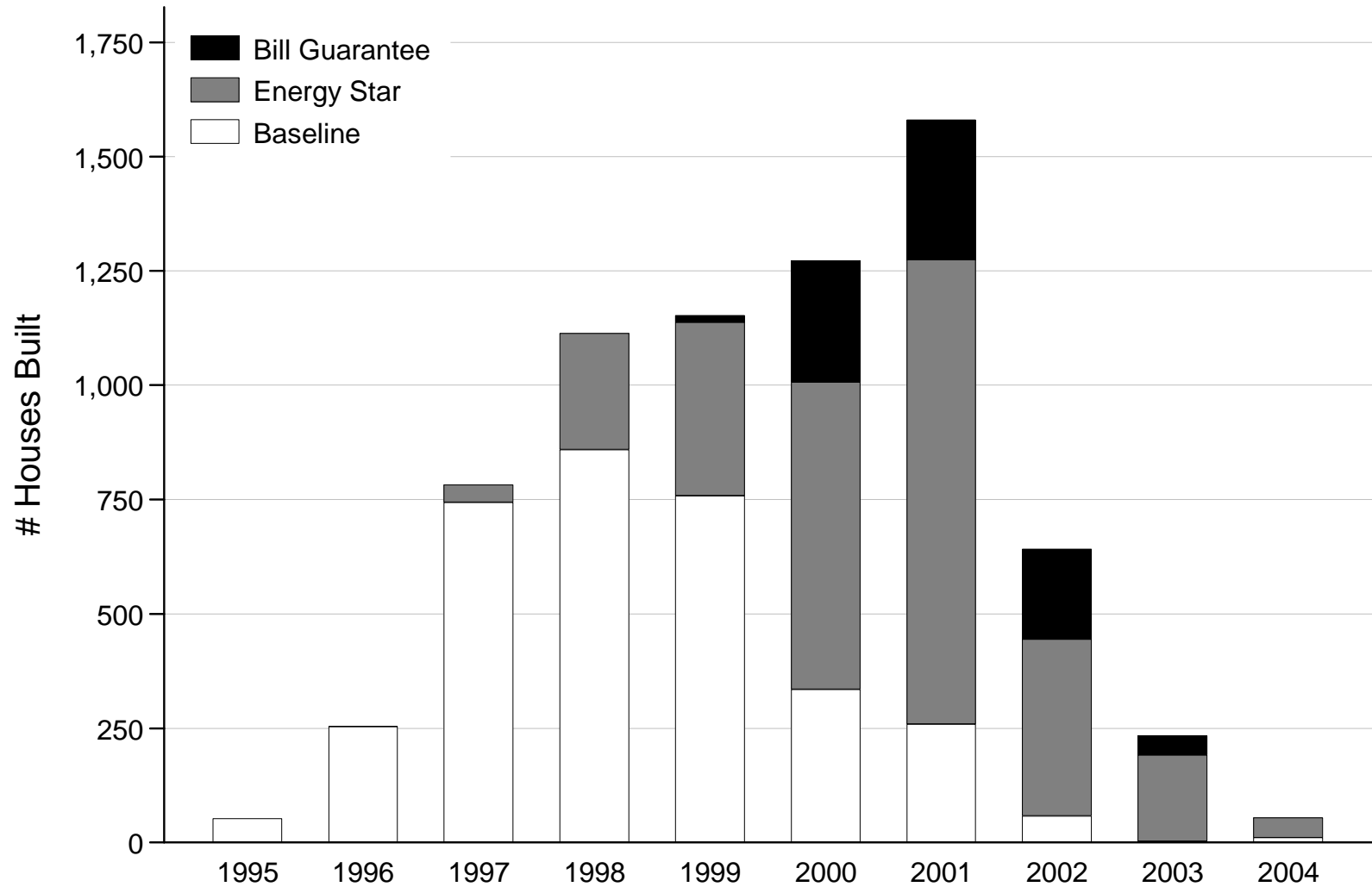




► Production by category & year built

Study Houses

units by year built and by house type





▶ **Baseline Homes: A moving target?**

- ▶ ENERGY STAR compliance primarily involved SEER 12 and/or low-e windows
 - > Phoenix construction (slab, stucco) is already tight
- ▶ But...many new homes already met these standards
 - > 2 builders: all SEER 12 A/C and low-e windows
 - > All but 1 builder used all SEER 12 A/C
- ▶ As 2 efficient builders switched production to ENERGY STAR, Baseline homes became less efficient
- ▶ Overall, slightly more than half of the Baseline homes were potentially already ENERGY STAR



▶ Regression Modeling of Electric Usage

▶ Some regression findings

- > 1800 ft² home with gas heat and no pool: summer/cooling loads are estimated at 6,413 kWh for average Baseline, 6,493 kWh for EStar, and 5,409 kWh for GPerformance (16% savings over EStar)
- > Compared to BaseReg, EStar use 10% less for summer/cooling and GPerformance use 25% less summer/cooling
- > Swimming pools are estimated to use by about 4500 kWh/yr. with about 750 kWh as added summer/cooling load. This large end use may be worth addressing (pump sizing/scheduling?)



▶ **Houston Energy Efficiency Study**

Using real world data evaluate the performance differences between baseline, ENERGY STAR® and Guaranteed Performance homes

Compare actual versus predicted performance, as well as identify construction techniques and products that deliver energy savings



▶ Why Houston?

- ▶ Metropolitan Houston has become one of the largest markets in the country for new housing construction, with more than 350,000 new homes started since 2000
- ▶ Same 3 home types as Phoenix and LOTS of them
- ▶ Well established local high performance home infrastructure
- ▶ Different Climate than other studies: Hot and HUMID
- ▶ Fairly consolidated network of manufacturers and trades – but not as consolidated as Phoenix



► Funding Partners



Blasnik and
Associates



▶ Study Methodology

- ▶ Methodology for Houston Evaluation Study
 - > Evaluate three house categories: baseline, ENERGY STAR & guaranteed performance
 - > Collect monthly electric and gas (when available) consumption data on all new hookups from 2002-2008
 - > Match usage data against building data collected from the ENERGY STAR homes database, appraisal data and Houston's largest home energy rating companies
 - > Compare annual consumption across house types and construction characteristics



▶ House Types

- ▶ What constitutes a baseline home?
 - > Any non-program home in CenterPoint's Metro Houston territory
 - > Must meet local energy code at a *minimum*



▶ House Types

ENERGY STAR

- > Backed by the EPA
- > More Energy Efficient than “Code”
 - From 2002-2006, 30% better than a reference home built to the 1993 Model Energy Code
 - From 2006-Present, 15% better than a reference home built to the 2006 IECC
- > Third Party Certified



▶ House Types

Typical ENERGY STAR Features:

- Higher SEER or AFUE
- Low-E Windows or Improved U-Values
- Duct Sealing and Testing
- Insulation QA
- Thermal Bypass Checklist, July 2006-Present



▶ House Types

- > Guaranteed performance specs are ENERGY STAR plus:
 - More stringent building infiltration and duct leakage standards
 - Right Sizing
 - Air Barrier Framing and Insulation QC (2000 - Present)
 - Ventilation
 - Pressure Balancing
 - Combustion Safety





► Data Sources

Data	Source
ENERGY STAR Homes Program Tracking Data, Electric & Gas Usage	CenterPoint® Energy
County Property Assessor Data	Brazoria, Fort Bend, Harris and Montgomery Counties
REM/Rate Files and Building Testing Data	Houston HERS Raters
Weather Data	National Weather Service
Housing Market Data	Manufacturers, Installers and Distributors



▶ Characterize the Houston Market

- ▶ Huge new residential construction market
- ▶ Different Climate: Hot and HUMID
- ▶ Consolidated: handful of key companies for each trade, many production builders, large home performance co's
- ▶ Huge developments: some with thousands of homes
- ▶ Adopted a residential energy code in summer 2001
- ▶ Major efforts around code training, ENERGY STAR, building science and consumer marketing outreach



▶ Electric Data: Usage Summaries

COMPOSITION OF DATA SET

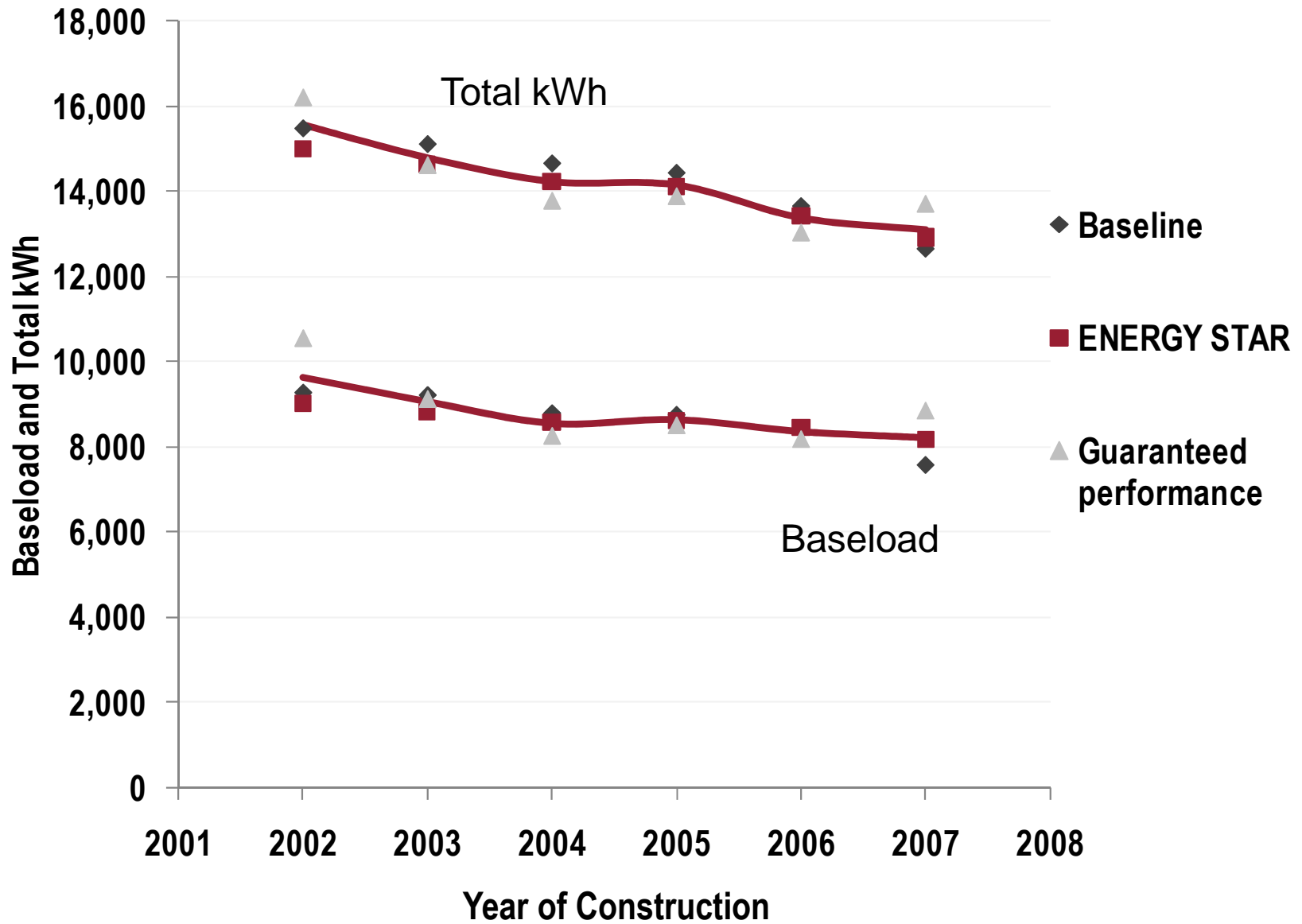
ENERGY STAR

Homes database, utility usage data, property assessor data, REM/Rate files, field testing files, weather data, manufacturer and distributor data

<i>Number of homes in study groups</i>	Overall analysis	Electric usage analysis	Gas usage analysis
Baseline	70,828	40,981	10,815
ENERGY STAR	81,755	42,154	15,301
Guaranteed performance	6,115	2,795	659
Total	158,698	85,930	26,775



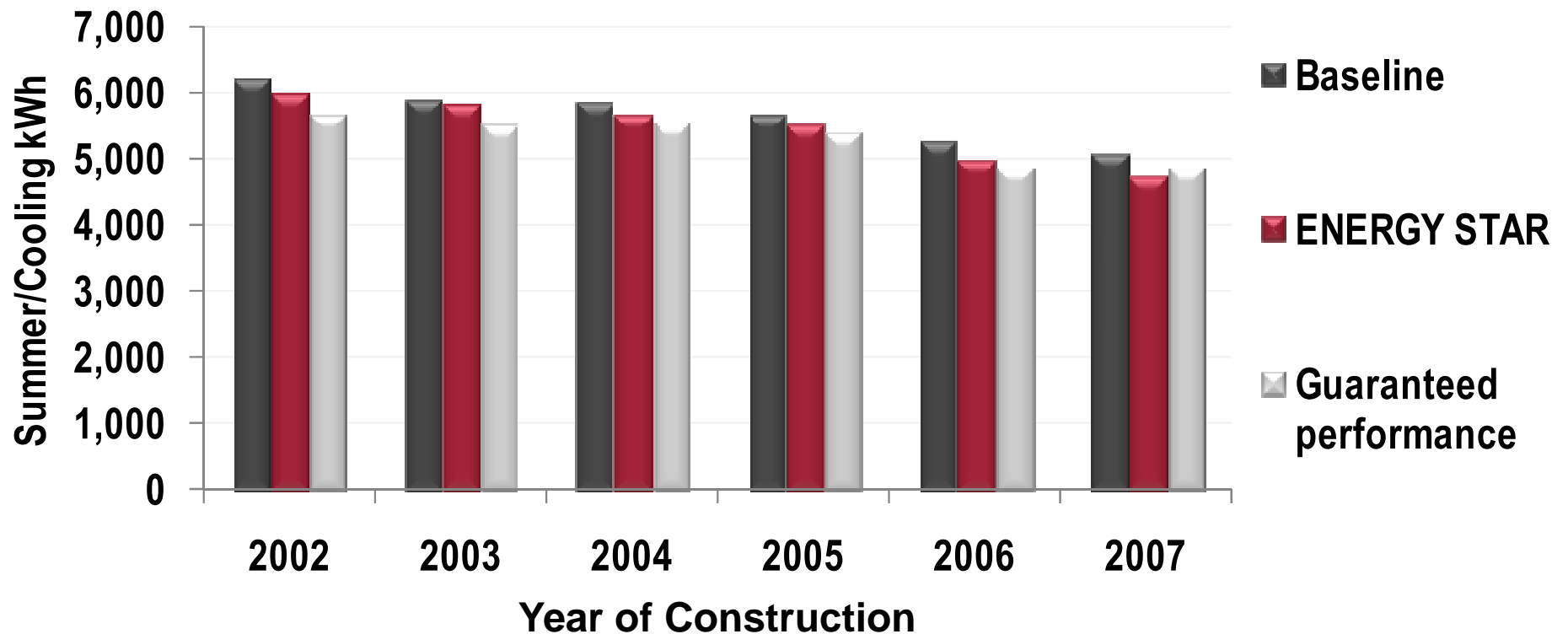
▶ 2008 kWh Usage





▶ Data Analysis and Results

2008 cooling usage by year of construction





► Overall Electric Usage

	Category			Difference vs. Base	
	Base	ES	GP	ES	GP
2008 Electric usage: unadjusted					
Summer/cooling	5,543	5,438	5,339	-105 ±27	-205 ±77
Baseload	8,511	8,533	8,849	22 ±60	338 ±175
Total kWh/yr	14,054	13,971	14,187	-83 ±77	134 ±222
2008 Electric usage: size adjusted					
Summer/cooling	5,770	5,471	5,394	-298 ±21	-375 ±60
Baseload	8,871	8,618	8,950	-253 ±53	79 ±157
Total kWh	14,641	14,089	14,344	-552 ±62	-297 ±183

- Baseload is bigger than cooling load in a hot climate like Houston – also responsible for about 20% of the cooling load
- Must find ways to reduce baseload if we want to achieve large overall savings



► Data Analysis and Results

**2008 difference in energy use from baseline homes
(adjusted for size but not vintage)**

	Percent Usage Difference vs. Baseline	
	ENERGY STAR	Guaranteed Performance
Summer/cooling kWh (2008)	5% less	6% less
Total kWh (2008)	4% less	2% less



► Construction Practices Across Groups

	RESNET Reference	Estimated Baseline	ENERGY STAR
Wall R-value	13	14	14
Roof/ceiling R-value	30	30	30
Normalized leakage, nL	0.57 (0.48)	?	0.40 (0.39)
Glazing U-factor, effective	0.75	0.54	0.54 (0.52)
SHGC	0.40	0.36	0.36
Percentage window area	18%	14%	14%
R-value return ducts	4	6	6
R-value supply ducts	8	6	6
Default distribution efficiency	0.80	?	~0.88
Furnace AFUE	78%	80%	80%
Air Conditioner SEER	10 (13)	11.5+ (13.5)	12.6 (13.7)
DHW, gas efficiency	0.54 (0.59)	0.54 (0.59)	0.59 (0.60)
DHW, electric efficiency	0.86 (0.91)	0.86 (0.91)	0.91

Note: changes in 2006 shown in brackets (2004 for DHW)



► Data Analysis and Results

REM/RATE™
ANALYSIS
Predicted
versus actual
usage

Cooling load projections and usage

Average load [kWh/yr]

REM/Rate	5,506
Billing data	5,677
Difference	171 [3%]

% Homes where REM/Rate within...

...10% of billing data	28%
...25% of billing data	64%
...50% of billing data	91%

Correlations with billing data

REM/Rate	0.62
Floor area, shell area	0.67



▶ Regression Modeling of ES Homes

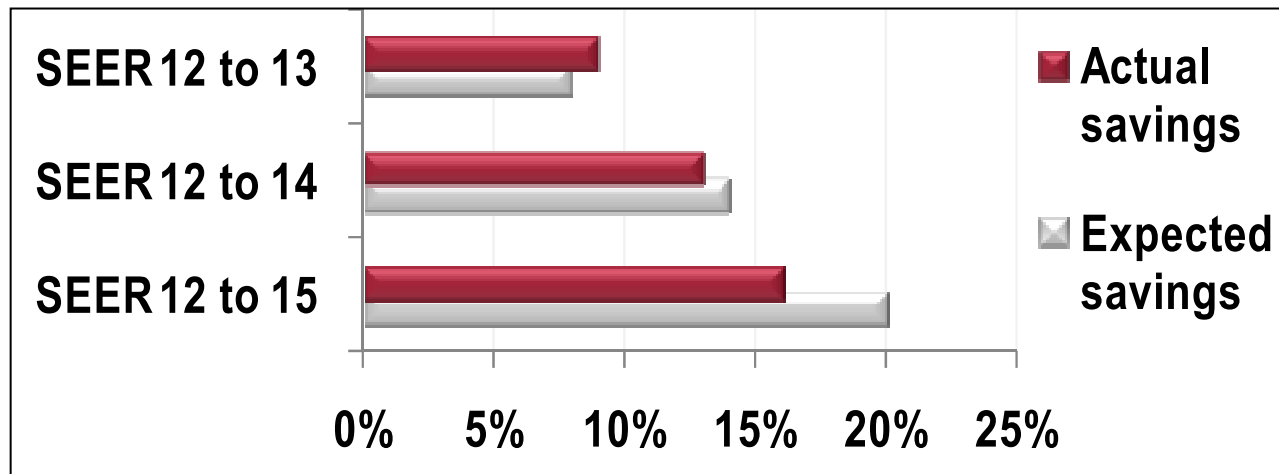
- ▶ Regression analysis used to assess how house data relates to summer/cooling usage
 - > 16,374 ES Homes with matching REM data
 - 3,254 with duct and shell field test data too
- ▶ Explored a variety of questions using multiple modeling approaches
- ▶ Report on relationships that appear solid



▶ Regression Modeling Findings (1)

▶ A/C SEER Savings vs. SEER12

- > SEER 13: 583 kWh, 9% (8% expected)
- > SEER 14: 787 kWh, 13% (14% expected)
- > SEER 15: 984 kWh, 16% (20% expected)



- > SEER changes account for 2/3 of ES Homes load reduction from 2005 to 2007



▶ Regression Modeling Findings (2)

▶ Building Shell Leakage

- > Summer/cooling ~ 0.4 kWh per CFM50
- > Infiltration Loads: 734 kWh/yr of cooling (14%) in average
1924 CFM50 home

▶ Duct Leakage

- > Summer/cooling ~ 2-2.5 kWh/CFM25 duct
- > Duct leakage loads: 174 kWh of cooling (3%) in average
87 CFM25 home



▶ Regression Modeling Findings (3)

- ▶ Radiant Barrier Roof Sheathing
 - > Reduces loads about .09 kWh/ft², equals about 180 kWh (3%) per home
- ▶ Baseload Electric Impact on Summer/Cooling Loads
 - > strongly related to summer/cooling loads at 0.13 kWh cooling per annual kWh baseload
 - About 1150 kWh -- 20% of cooling load is removing baseload heat
- ▶ Baseload Electric Loads
 - > related to house size (floor or shell) and assessed value of home
 - > Baseload kWh/yr ~ $2900 + 1.8 * \text{floor area} + 6.5 * \text{Assessed Value}$ (\$1000s)



► Gas Usage Findings

	Category			Difference vs. Base	
	Base	ES	GP	ES	GP
Number of homes	10,815	15,301	659		
Floor area	2,353	2,446	2,412	93 ±19	59 ±60
Envelope area (above grade)	4,134	4,255	4,239	121 ±22	104 ±71
One-story home	61%	60%	43%	-2%	-18%
Gas usage: unadjusted					
Winter/heating	264	258	238	-6 ±3	-26 ±10
Baseload	174	165	162	-10 ±2	-12 ±7
Total therms/yr	438	423	400	-16 ±4	-38 ±13
Gas usage: size adjusted					
Winter/heating	274	259	243	-15 ±2	-31 ±8
Baseload	184	168	167	-16 ±2	-17 ±6
Total therms/yr	458	427	410	-30 ±3	-48 ±10

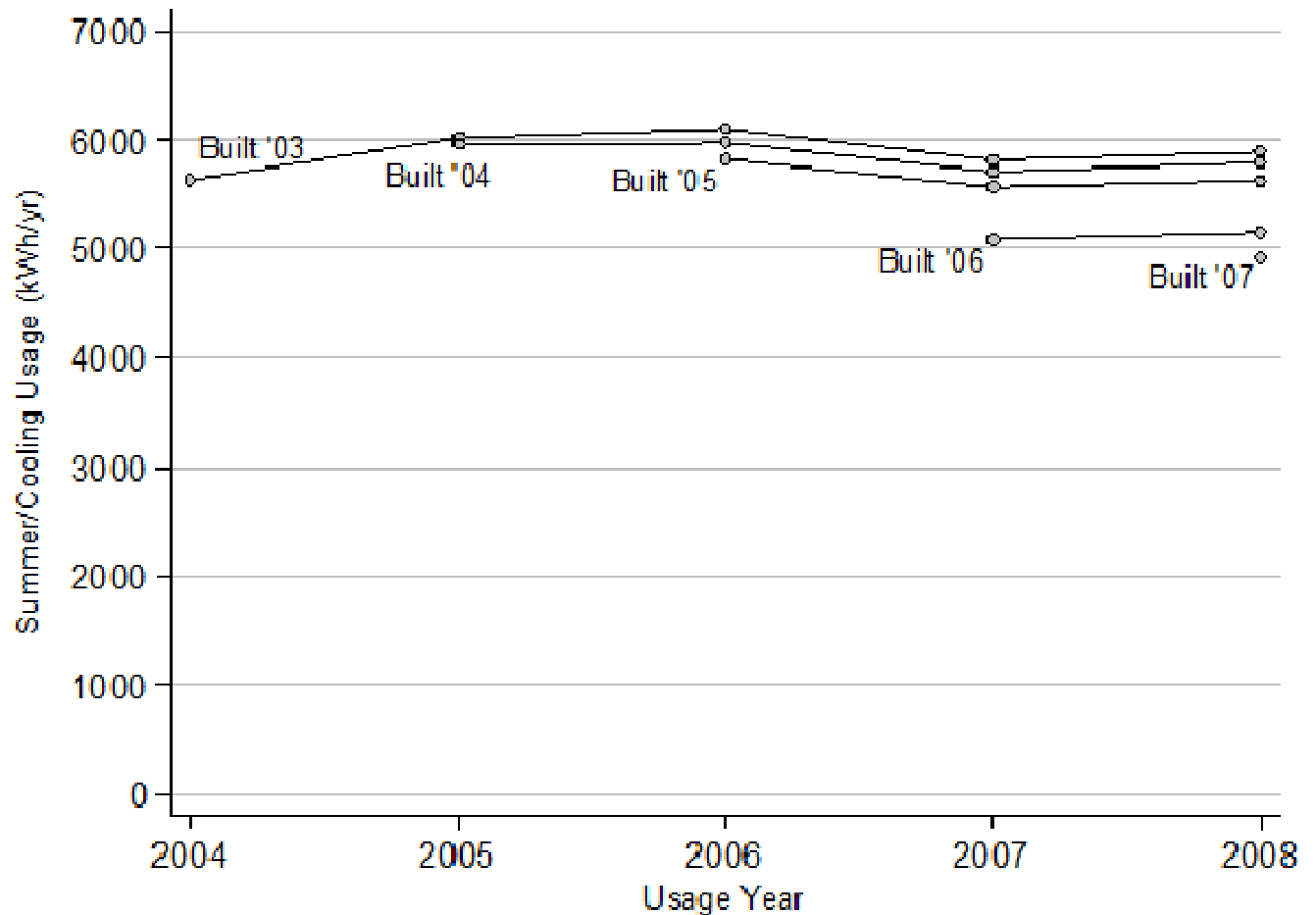


► Usage Trends Over Time: Cooling

Could differences between home vintages be an occupancy effect?

Maybe cooling use increases over time for a home?

Not in these homes...

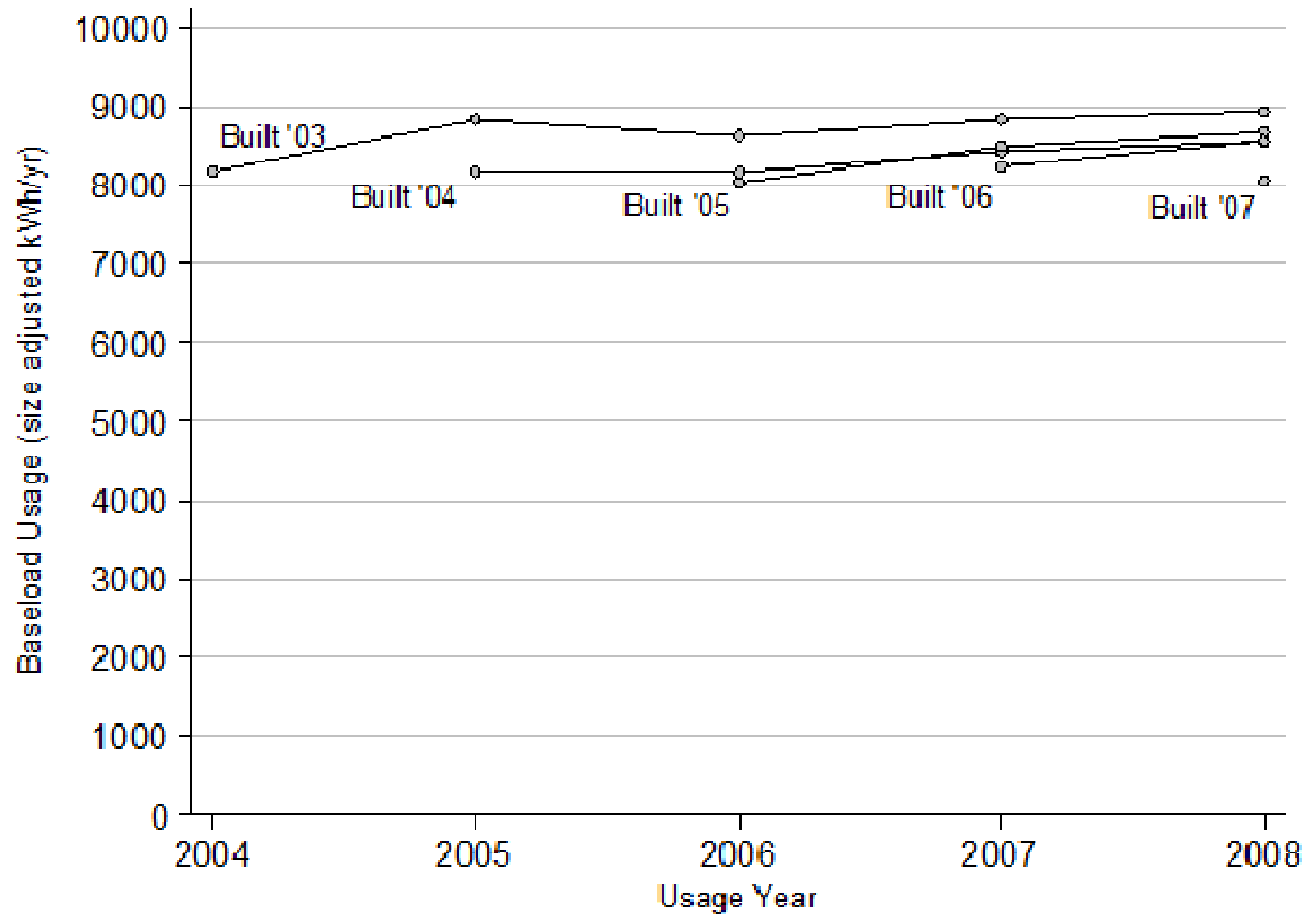




► Usage Trends Over Time: Baseload

Baseload does increase some over time...

so comparing across years may be less useful



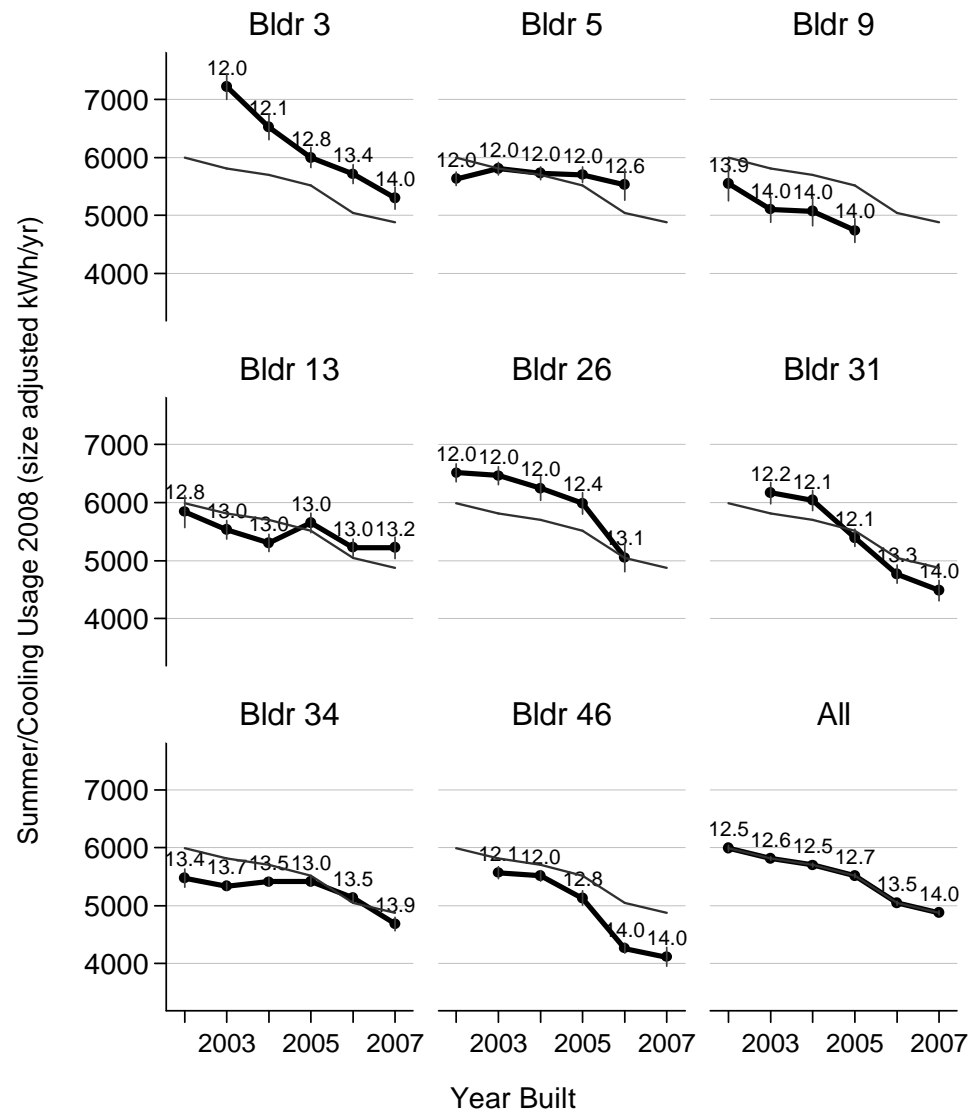


► Builder Effects

Graph of Cooling Use vs. Year Built by builder

Labeled with avg SEER

Builders with largest cooling declines over time showed large AC SEER increases





▶ Conclusions

- ▶ ENERGY STAR homes perform very close to the predictions of the models, but baseline homes perform much better than the reference homes defined by the HERS standard.
- ▶ Why? Because the reference home rarely if ever actually got built. And some the assumptions about “typical” homes established by the standards may be incorrect.



► Conclusions

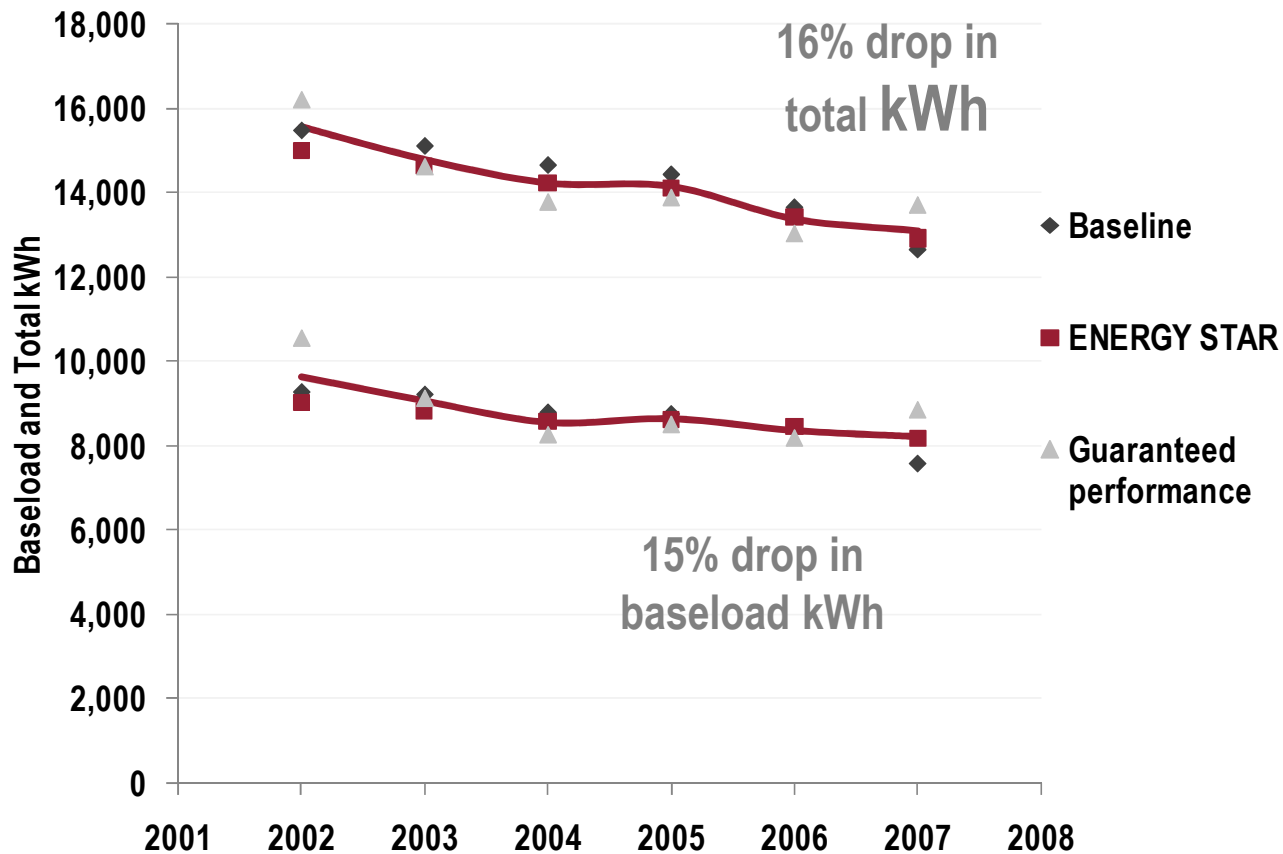
- As a result, savings between program homes and Baseline homes in Houston are small

	Percent Usage Difference vs. Baseline	
	ENERGY STAR	Guaranteed Performance
Summer/cooling kWh (2008)	5% less	6% less
Total kWh (2008)	4% less	2% less



▶ Conclusions

▶ All New Homes in Houston Are More Efficient





► Conclusions

Why only 3-5% lower use in ENERGY STAR?

- > 2001 IECC went into effect in Texas September 2002
 - SHGC <0.4 windows (30% cooling savings vs. std 0.73 SHGC)
 - R-8 ducts with mastic seal on all seams if outside conditioned space
 - R-6 ducts acceptable if AC SEER 14
 - Seal recess can lights
 - R-19 attics (everyone used R-30)

- > 2006 federal SEER minimum standard increased
 - 11% drop in baseline home cooling after SEER-13 standard; shows that they weren't SEER-10 before



▶ Conclusions

Spillover effects of ENERGY STAR?

- > Duct testing, adoption of mastic for duct sealing & training
- > Building tightness standards, air barrier framing practices

**Positive spillover effects would reduce observed
“savings” when they should increase impact
estimates**



▶ Lessons Learned

▶ WHAT DOES HOUSTON TELL US?



▶ Lessons Learned

- ▶ ENERGY STAR may have helped facilitate code compliance in Houston
- ▶ Most builders in Houston are working with a home performance contractor – either to build to a program or to comply with the code.



▶ Lessons Learned

- ▶ Billing analysis can provide accurate measurement of program results and clarifies what specs provide savings
 - > Also allows you to benchmark current building practices and develop standards that fit your marketplace



▶ Where do we go from here?

- ▶ We need to clarify our models and assumptions
- ▶ Is there a need for increasing the ENERGY STAR standards?
- ▶ What is the relationship between ENERGY STAR and other high performance home program's to codes and construction markets?



▶ Where do we go from here?

- ▶ What else can we learn from Houston?
 - > Are ENERGY STAR houses holding their value?
 - > Differences within groups of program homes?
 - > Are there more energy “hogs” in any particular group?

- ▶ How does this play out in different markets and climates?

- ▶ Are consumers happier with these homes?

- ▶ What else?

THANKS

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